Original Article

The effect of corticision on root resorption with heavy and light forces

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ABSTRACT

Objective: To investigate the association between corticision and different force magnitudes with the amount of root resorption.

Methods: Forty-four male Wistar rats (7 week old) were evaluated after an orthodontic spring delivering either 10 or 100 g was placed on the left maxillary first molars to move molars mesially. Experimental rats were divided into four groups, with 11 animals in each group: (1) LF, no corticision and 10 g of orthodontic force; (2) LFC, corticision and 10 g of force; (3) HF, no corticision and 100 g of force; and (4) HFC, corticision and 100 g of force. Contralateral sides were used as unloaded controls. The total duration of the experimental period was 14 days. Two-dimensional (histomorphometric) and three-dimensional (volumetric, micro-focus X-ray computed tomography [microCT]) analysis of root craters were performed on maxillary first molars.

Results: Histomorphometric and microCT analysis revealed a significant amount of resorptive areas in the experimental groups when compared to unloaded controls. However, no significant difference was detected in the amount of resorption among the four experimental groups.

Conclusions: At day 14, neither the amount of force nor the cortical incision caused significant effect on root resorption that was registered by histomorphometric or microCT analysis. (*Angle Orthod.* 2016;86:17–23.)

KEY WORDS: Corticision; Orthodontic force; Tooth movement; Root resorption

INTRODUCTION

Orthodontic tooth movement is a tightly regulated process of bone resorption and formation. Numerous approaches to accelerate tooth movement have been studied with the goal of reducing treatment time while also minimizing damage to the dentition and periodontium. Root resorption, defined as the active removal of mineralized cementum and dentin,[1] is one of the primary negative sequelae associated with orthodontic treatment, with severe cases resulting in increased mobility of teeth and potentially early loss of affected teeth. Although root resorption may in part be a physiologic phenomenon, there are predisposing factors that may increase the risk, including the type and mechanics of orthodontic force delivery,[2–4] magnitude and duration of the force,[5–7] age of the patients,[8,9] and some medical conditions like endocrine disorders[10] and asthma.[11]

Defining the optimal magnitude of orthodontic force that yields the maximal extent of tooth movement without negative effects on the root, periodontal ligament, and alveolar bone continues to remain elusive. There are many studies in humans and experimental animals that have reported minimal root resorption with light forces, whereas heavier forces resulted in significant crater formation.[5–7,12–16] However, some clinical studies in adolescents have shown that by increasing the orthodontic force by several fold, tooth movement increased by 50%, but without detectable changes in occurrence or severity of root resorption.[17]

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Accepted: February 2015. Submitted: December 2014.
Published Online: April 1, 2015

Previous studies have shown some correlation between bone turnover and tooth movement or root resorption. Higher bone turnover rates have shown increases in tooth movement without affecting root resorption in contrast to decreased bone turnover rates, which may increase the risk of resorption.[18] A study in calcium-deficient rats showed higher amounts of tooth movement and decreased areas of root resorption, which confirmed the theory that decreased bone density facilitated remodeling of alveolar bone instead of root surfaces.[19]

Many efforts have been made to develop methods that could increase alveolar bone remodeling and accelerate orthodontic treatment. One of the methods being utilized is corticision, which was introduced as a supplemental dentoalveolar surgery in orthodontic therapy to achieve accelerated tooth movement with minimal surgical intervention. By reducing alveolar resistance to tooth movement and accelerating alveolar bone turnover rate by means of a regional acceleratory phenomenon, corticision may have the potential to reduce the treatment time and minimize side effects including root resorption.

In most studies, resorption has been quantified in histologic sections by surface area measurements of resorption craters.[9] Recently, one of the most detailed three-dimensional software analyses of root craters was introduced by Chan and Darendeliler.[6] This analysis relies on the scanning electron microscopic technique where serial images are taken at a $\pm 3^{\circ}$ rotation to obtain a stereo image and the volume of the crater on the extracted teeth. This allows enhanced visual and perspective assessment of root surfaces with more accurate quantitative measurements.

The aim of this study was to quantify the amount of root resorption as it relates to corticision and distinct orthodontic force levels at 14 days of tooth movement. Root resorption was analyzed by two different ways: (1) in two dimensions using histomorphometric analysis where the surface of eroded areas was analyzed on histologic sections and (2) in three dimensions (volumetric) using the serial micro-focus X-ray computed tomography (microCT) sections, which allowed presentation of root volumes in rat molars.

MATERIALS AND METHODS

Study Design

Forty-four male, 7-week-old Wistar rats (body weight 150–250 g) were analyzed with approval from the Institutional Animal Care Committee (ACC 2010-668). The experimental design utilized four groups, each with 11 rats: (1) LF, no corticision and 10 g of force; (2) LFC, corticision with 10 g of force; (3) HF, no corticision and 100 g of force; and (4) HFC, corticision with 100 g of force. Six rats were randomly selected from each experimental group for histomorphometric analysis and the other five rats were used for microCT measurements.

Experimental Tooth Movement

In anesthetized rats, 9-mm springs delivering 10 g of force (Ultimate Companies Inc, Bristol, Conn) or 10-mm springs delivering 100 g of force (GAC, 10-000-03) were placed between left maxillary first molars and incisors as previously described.[20] Springs were activated for 1 or 2 mm, depending on the spring type (Figure 1A) and reactivated 1 week after their application. Right maxillae were not loaded and were used as a control. The duration of the experimental period was 14 days.

Application of Corticision

Corticision was applied at the time of orthodontic appliance placement and 1 week after as previously described.[20] Briefly, corticision was performed on the mesiopalatal aspect of left maxillary first molars (Figure 1A). The tip of a reinforced surgical blade (No. 11, Bard-Parker, Franklin Lakes, NJ) capable of making a surgical incision with a minimum thickness of 400 μm was employed. The blade was positioned on the mesiopalatal gingiva, 0.5 mm from the corresponding tooth surface at an inclination of 45°–60° to the long axis of the maxillary first molar. The blade was inserted, gradually penetrating the overlying gingiva, cortical bone, and cancellous bone (Figure 1B).

Registration of Root Resorption

Histologic analysis. Upon completion of the experiments, rats were euthanized by CO_2. Maxillae were dissected, hemisected, and placed in 10% formalin at $+4^{\circ}$C for 7 days. Following fixation, tissues were decalcified in 14% EDTA at $+4^{\circ}$C for 4 weeks, dehydrated in a graded series of ethanol, embedded in paraffin, and cut into serial 5-μm sagittal sections. Sections were stained with hematoxylin and eosin, and midsections of the distobuccal and mesial roots were chosen for histomorphometric analysis (Figure 2A through E). The erosions were traced by Osteomeasure Software (OsteoMetrics Inc, Decatur, Ga) (Figure 3A,B). Root resorption was evaluated by identifying discontinuities along the root surface. Points were placed at the margins of each break in continuity of the root surface, and then connected. The enclosed area was considered a resorptive crater. The total resorptive area was calculated by summing all of the resorptive crater areas on the mesial side of the distobuccal root and then divided by the total dentin area. For each sample, three

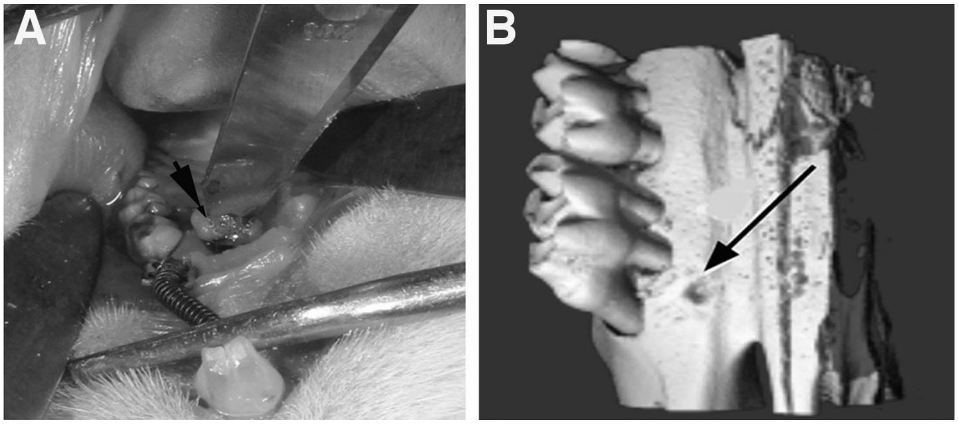

Figure 1. (A) Tooth movement model. Spring delivering either 10 or 100 g of force was activated from the left maxillary first molar to the incisor. Arrow shows the place of blade incision. Resin around the tip of the surgical blade allowed penetration no more than 0.5 mm. (B) Three-dimensional microCT reconstruction of left maxillae viewed from the palatal side (P) immediately after application of corticision. Alveolar bone defect confirmed cortical penetration of the surgical blade (arrow).

to five sections were analyzed and their mean value was used to run statistical tests.

MicroCT analysis. During the fixation period, image arrays of the maxilla were collected using microCT. Three-dimensional images were constructed using standard convolution and back projection algorithms with Shepp and Logan filtering and rendered within a 16-mm field of view at a discrete density of 578,704 voxels/mm^3 and a spatial resolution of 16 μm. The customized software was used to segment five roots of the maxillary first molar and to measure their volumes by contouring the root surface on two-dimensional slices. The crowns were not included in the measurements and the separation line (crown–root) was placed at the points demarcating the cementoenamel junction.

Total volume included all of the structures within the root including the pulp. Root volume (RV) was restricted to the root dentin, and as a representation of root resorption was used in the statistical tests.

Statistical Analysis

Statistical analyses were carried out using Graph-Pad Prism Version 5.0a (GraphPad Software Inc, La

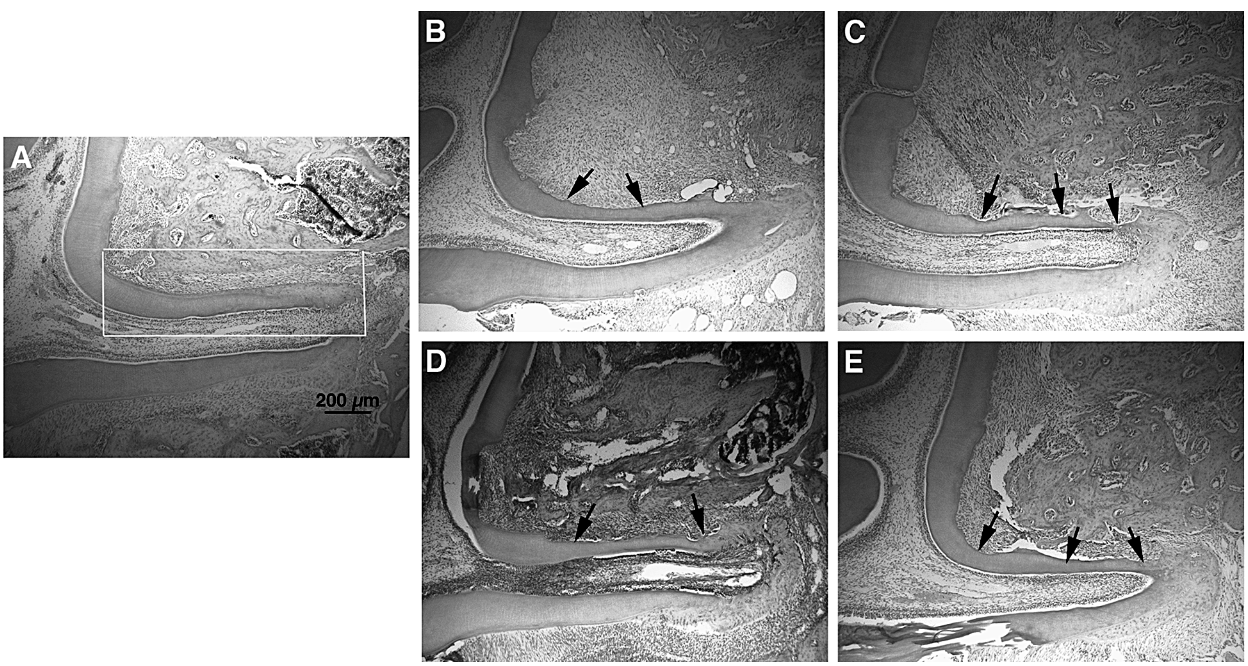

Figure 2. Histological evaluation of root resorption in (A)Control, (B)LF, (C)LFC, (D)HF, and (E)HFC groups. Distobuccal root of the first left maxillary molars (5x magnification). Arrows point the erosions present on the mesial side. White box represent the area used for histomorphometrical analysis.

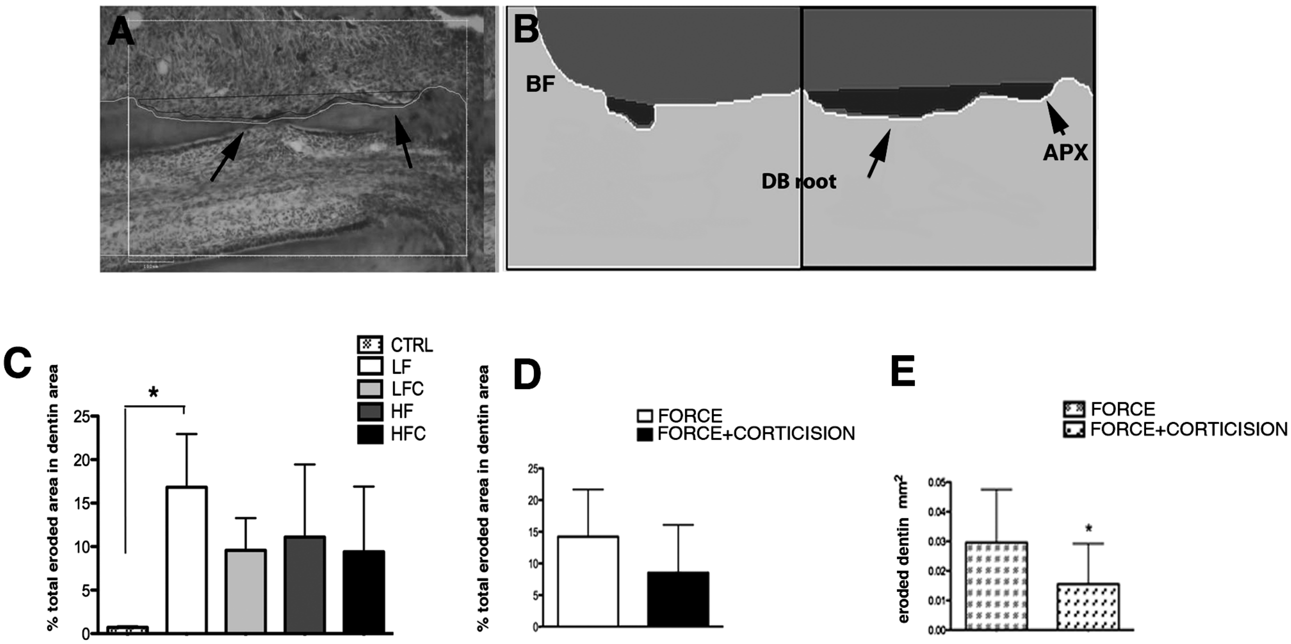

Figure 3. (A) Example of erosion tracing using the Osteomeasure Software. Blue line follows the surface of eroded surface, and the most prominent points on the root surface were connected making a new line of closure and defined a resorptive crater (10× magnification). (B) Example of eroded areas (blue) on the compression side of distobuccal root (gray) traced by histomorphometric method. Total surface of all erosions were measured from apex (APX) to bifurcation (BF) (10× magnification). (C) Graph of histomorphometric analysis. Each value represents mean (SD) (n = 6). Significance was detected between control and LF groups ($P = .0212$). (D and E) Graphs showing the significance when groups were pooled. Bars represent the percentage of eroded area normalized per dentin ($P = .0905$) (D) or absolute amount of eroded area ($P < .05$) (E).

Jolla, Calif). Statistical significance of differences among means was determined by one-way analysis of variance (ANOVA) with a Bonferroni post-hoc test and by unpaired *t*-test. Significance was accorded when $P < .05$.

RESULTS

To study the effect of corticision with different force levels on the root surface, the size of root surface craters along the distobuccal root was calculated using histologic specimens. Histomorphometric analysis of the loaded (left) maxillary first molars showed that erosion areas were mostly present on the compression (mesial) side of the root (Figure 2B through E). The mean (SD) percentage of eroded area in total dentin area on the mesial side of distobuccal root in the LF group was 16.8% (6.1%), in the LFC group 9.6% (9.0%), in the HF group 11.09% (8.3%), and in the HFC group 9.4% (7.5%), while in unloaded sides was 0.7% (0.1%). When all five groups were compared, significance was detected between the control and LF groups (ANOVA, $P = .0212$) (Figure 3C). Although experimental groups with corticision showed slightly less eroded surface than the groups without corticision (in either heavy or light force), when ANOVA was applied on only four experimental groups, no significant differences were evident ($P = .3391$). When groups were pooled, there was a significant decrease in the eroded area for the corticision groups ($P < .05$) (Figure 3E).

In volumetric, microCT analysis, we used the RV parameter to visualize the amount of root resorption. RV mean (SD) in the LF group was 1.598 (0.182) mm^3, in LFC was 1.629 (0.181) mm^3, in HF was 1.710 (0.287) mm^3, and in HFC was 1.888 (0.219) mm^3, while in unloaded controls RV was 2.248 (0.122). When ANOVA test was applied to all five groups, significance was detected ($P = .0003$), and Bonferroni post-hoc test showed statistical significance between the control and LF groups, control and LFC groups, and control and HF groups (Figure 4F). However, when ANOVA test was applied on only four experimental groups, no statistical significance was detected ($P = .1970$).

DISCUSSION

The primary objective of this study was to understand the role of force magnitude on root resorption as well as the impact of corticision on modulating the resorptive process in a rat model. Root resorption occurred with the application of both light (10 g) and heavy (100 g) forces. While historically higher forces have been associated with the severity of root resorption,[5–7,12–15] both methods for its detection in this study did not show

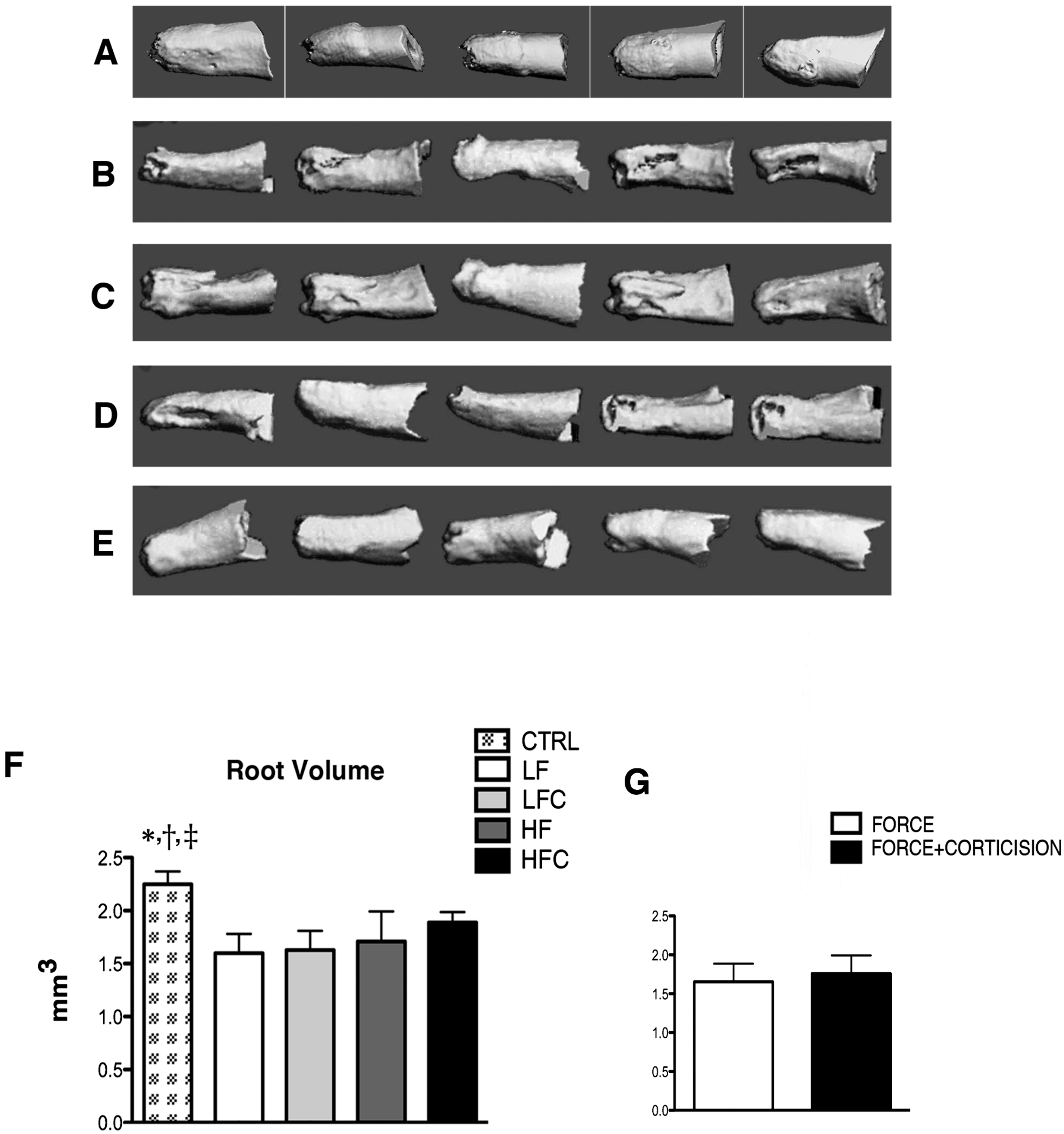

Figure 4. MicroCT images of the surface of distobuccal root in (A) control, (B) LF, (C) LFC, (D) HF, and (E) HFC groups. (F) Graph showing quantification of root resorption using microCT method (n = 5). *, †, ‡: Significance to LF, LFC, and HF groups ($P = .0003$). (G) Graph showing the difference when groups were pooled ($P = .3284$).

a difference in the amount of resorption between light and heavy forces. This finding confirms recent reports that found great variation in the degree of tooth movement with the application of light forces and variation in the appearance of focal hyalinization related with the development of root resorption.[21,22]

Recent findings by Nakano et al.[13] suggest that during a tipping type of tooth movement (which occurs in our model), root resorption increases steeply with an increase in the applied force from 10 to 25 g. Further force increase from 25 g to 50 g and finally to 100 g had no effect on the degree of resorption. Noda et al.[23]

reported that root resorption occurs when force magnitude exceeds 1.6 g and that the amount of resorption is influenced by force increase from 0.8–4 g but not those exceeding 8 g. In our experiments, it might have happened that both forces reached the "plateau" in creating the resorption pits.

Age may be an important factor in the development of root resorption. In this study, relatively young rats were studied and the findings are consistent with studies in a human adolescent population,[17,24] which did not find higher amount of root resorption with the application of increasing force levels.

Duration of experiments could have also an impact on our results. Some studies in rats reported that at 14 days of orthodontic treatment, the differences in root resorption area between light and heavy forces were not as pronounced as the differences seen at day 28.[5] Paetyangkul et al.[25] showed that the highest difference in the severity of root resorption between light and heavy force in humans occurred at 8 weeks.

It has been hypothesized that higher bone turnover increases tooth movement without affecting the root resorption, and decreased bone turnover increases the risk for root resorption.[18] Based on this premise, a corticision, which stimulates an inflammatory process and ultimately a bone remodeling process, has a potential to "protect" root integrity. Kim et al.[26] showed that corticision in cats causes less hyalinization, more rapid removal of hyalinized tissue, and higher bone apposition, confirming that corticision could accelerate bone remodeling. Similar findings were reported by Iino et al.[27] Based on these studies, we hypothesized that the amount of root resorption would be less evident in the experimental groups where additional corticision is applied. Unfortunately, we were unable to see an effect on hyalinization, presumably because any changes had been resolved at the time of our evaluation at day 14.

In this current study, histomorphometric evaluation of root resorption craters showed that groups with corticision had slightly decreased amount of root resorption (not significant). Moreover, when groups were pooled (LF + HF vs LFC + HFC) (Figure 3E), there was a significant decrease in corticision groups. MicroCT analysis showed a similar trend. These findings suggest that corticision may cause a mild osteopenia, slightly enhanced periodontal ligament turnover, and a minimal increase in periodontal ligament vascularity, thereby reducing root resorption.

Root resorption occurs in three dimensions, and two-dimensional measurements may be confounded and not provide a fully accurate representation of the three-dimensional situation. However, the histomorphometric method provided a higher resolution for the assessment of resorption craters and measurements.

Data derived from this study reflect a relatively short period of orthodontic force application, and future studies are needed to evaluate differences in the resorption at a later time point. Performing experiments with older age groups could reveal more information about the incidence and severity of root resorption in our experimental groups.

MicroCT analysis was performed on the maxillary roots still enclosed in intact alveolar bone. Proper separation (extraction) of the maxillary roots from the alveolar bone that will allow scanning of isolated, small specimens at a high resolution, like scanning electron microscope technique, will definitely provide more reliable measurements of root resorption pits.

In summary, histomorphometric (two-dimensional) and microCT (three-dimensional) methods did not show a significant difference in the amount of root resorption between experimental groups, suggesting that neither the amount of applied force nor corticision have a significant effect on the incidence or severity of root resorption after 14 days of orthodontic tooth movement in young rats.

CONCLUSIONS

- No difference in root resorption was observed between 10 and 100 g of force measured by two-dimensional histomorphometry or three-dimensional microCT.
- Corticision did not show significant effect on the amount of root resorption at a force magnitude of 10 or 100 g.

ACKNOWLEDGMENT

The work in this paper was supported by American Association of Orthodontists Foundation (AAOF) Biomedical Research Award.

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